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SHORT COMMUNICATION

Excretion behavior of adult female crab spiders *Misumena vatia* (Araneae, Thomisidae)

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Abstract. Excreta potentially provide parasites or predators with information about the presence of hosts or prey; hence, vulnerable individuals experience strong selection to minimize danger from this source. Alternatively or additionally, excreta could alert potential prey to a spider's presence. Adult female crab spiders *Misumena vatia* (Clerck 1757) exhibited a strong reluctance to excrete when retained under tightly confined conditions. Only 5% of regularly fed individuals (1% of total observations) excreted over observation periods of as many as 50 days while confined in 7-dram vials (5 cm high, 3 cm diameter). Individuals retained large amounts of excreta during this time. However, when released upon vegetation over two-thirds of them excreted within 5 min, after moving to the distal end of a leaf or petal such that the excreta fell below them onto lower vegetation or the substrate. In the field they showed little tendency to excrete close to their hunting sites. The ability to retain excreta should serve this relatively sedentary species well in situations where it suffers high rates of attack or may reveal its presence to potential prey.

Keywords: Defecation, parasite avoidance, predator avoidance, retention behavior

Many animals may experience risks in voiding excretory material, which likely enhance the possibility of alerting predators and parasites to their presence and increase the danger of disease. Alternatively or additionally, the presence of excreta could forewarn potential prey to a predator's presenee. Considering the importance of these factors, surprisingly little attention has focused on studies examining the responses of predatory invertebrates to host or prey waste products (Weiss 2006). In particular, workers have written little about excretion in spiders (Curtis & Carrel 2000) or other arachnids (Sato et al. 2003; Sato & Saito 2006). In fact, Curtis & Carrel (2000) believed their paper on excretion behavior by garden spiders *Argiope aurantia* Lucas 1833 (Araneidae) (referred to as defecation behavior by the authors) to be the first explicit study of its sort on a spider, although Tietjen (1980) reported on the nonrandom distribution of excreta under laboratory conditions in *Mallos gregalis* (Simon 1909) (Dictynidae). Throughout this paper I use the term "excretion" (exereta, excrete, etc.) to identify the materials passing through a spider's anus, since the majority of this material consists of the products of post-assimilatory metabolic processes from the Malpighian tubules, rather than undigested matter.

In response to the risk of this material providing cues to their presence, potential prey or hosts might develop behavioral responses that minimize this threat, such as excreting away from their normal activities or retaining excreta indefinitely until they can safely void them. Taxa that show high fidelity to a site should experience particularly strong pressure to develop such tactics, as demonstrated by Weiss (2003, 2006) for caterpillars.

Crab spiders *Misumena vatia* (Clerck 1757) (Thomisidae) typically occupy flowers as sit-and-wait predators of insects and in the process may often remain at hunting sites for several days at a time. Excretion in these areas could attract a large number of predators and parasites through either visual or olfactory cues provided by this material. Although various vertebrates are usually considered the most common predators of spiders, they only infrequently prey on *Misumena* in coastal Maine, where I conducted this study (Morse 1985, 2007). More important are other invertebrates, especially spiders, predatory wasps, and parasitoid wasps and flies (Morse 1988a, 1988b), some of which likely respond to olfactory cues.

Here I characterize the excretion behavior of adult female *Misumena* retained for extended periods under confined conditions and then provided with sites that allowed them to dispose of their excreta some distance away from their hunting sites. I quantified the spiders' frequency and size of excretion when confined to small vials and immediately following their release onto vegetation, both flowers in the laboratory and leafy vegetation in the field. I also report observations on the excretion patterns of free-ranging adult females in the field. In combination, these results allow me to test whether these spiders discriminate among potential excretion sites, whether the spiders' ability to separate themselves from their excreta affects which sites they use for this purpose, and whether the site affects the size of the excretion.

METHODS

Adult female *Misumena* are medium-sized spiders that molt into the adult stage at 35–60 mg and may exceed 400 mg when they lay their single egg mass. These spiders have two large, raptorial anterior pairs of legs and two mueh smaller posterior pairs. They can change their color between white and yellow, and most have a prominent pair of deep red dorsolateral abdominal stripes.

Misumena frequent old fields and roadsides in my study area (South Bristol, Lincoln County, Maine, USA), where they hunt on flowers for large prey. I collected 72 adult females from these sites in June and July for studies unrelated to this one. The design of that work dictated in part the types of observations that I could make for this study. I kept the spiders in 7-dram vials (5 cm tall, 3 cm diameter) at ambient temperature and light regimes and fed them a moth (Noctuidae, Geometridae) or large fly (Syrphidae, Muscidae) every other day. Adult female spiders grew rapidly on this diet and did not require supplementary liquids. In the process I retained individuals for several days to well over one month. Retention times of the spiders varied in accordance with their mass upon capture and how rapidly they gained mass up to the point of egg laying. I recorded excretions when feeding the spiders and cleaning their vials after feeding or excretion. I did not start recording retention times of excreta by the spiders until they had been in the vials for two days to ensure that all individuals were in a similar hunger state. These spiders will usually take a large prey item every other day (Morse & Fritz 1982). Numbers of drops of excreta were counted whenever possible.

For the laboratory observations, I released female *Misumena* from their vials onto a flower, either an oxeye daisy *Chrysanthemum leucanthemum* or black-eyed Susan *Rudebeckia hirta*, and observed their behavior. I then counted all excretions produced within the next five minutes. Previous observations had demonstrated that the females often excreted immediately after release on a flower, particularly if I had retained them for several days before release (D.H. Morse, unpub. obs.).

I placed another group of previously confined adult females in the field on young, non-flowering milkweed *Asclepias syriaca* plants, sites previously recognized as favored nesting places (Morse 1985). Upon releasing spiders onto the plants, I observed these individuals for five minutes to determine whether they would excrete during that period, since earlier unrelated observations had established that they often excreted within this time.

I also tested the frequency with which free-ranging adult female *Misumena* excreted in conspicuous hunting sites on wild marjoram *Origanum vulgare* over periods as long as 17 days. These marjoram stems averaged 0.5 m in height and grew densely at the test site, which contained several hundred flowering stems. They bore terminal rounded panicles composed of multiple small pinkish-purple flowers. Immediately below their inflorescences marjoram stems bear dense ovate leaves, such that the hunting sites in marjoram occur in the top of a dense canopy of flowers and leaves. This situation made it difficult for spiders to excrete from their hunting sites without soiling nearby vegetation.

RESULTS

Characteristics of behavior and excreta.—*Misumena* exhibited distinctive excretion behavior: individuals moved to the tip of a petal or leaf, raised themselves on their two pairs of large forelimbs, the two smaller pairs of posterior limbs usually not contacting the substrate at this time, and then released varying numbers of drops of a whitish liquid with dark brown flecks that quickly dried in the air to a dirty light brown. Upon release onto the flowers the spiders typically commenced excretion behavior quickly, often within the first 30 seconds. In the laboratory, excretions made from the tips of flower petals fell onto the substrate below; in the field they most often completely cleared the plant in question, landing on the grass in the substrate. When voided from milkweed leaves in the field, the excreta most often landed on another leaf of the plant below the excretion site. If permitted to climb to the rim of their vial the spiders readily excreted from there as well, exhibiting the same behavior as seen on the petals and leaves (D.H. Morse, pers. observ.).

During large excretions in which the spiders voided many drops, they released most of these drops in a nearly constant stream, so that my counts of these drops were approximate. These excretions averaged 5.0 ± 0.97% (± SE, n = 6) of the previous body mass (D.H. Morse, unpub. data). The spiders distinctly spaced these drops in smaller excretions.

Tendency to excrete.—I recorded only four excretions in the vials during the feeding and cleaning sessions that took place every second or third day. These involved 72 spiders and 335 observations of spiders at these sessions, with spiders present for 1–15 such sessions (5.6% of the spiders and 1.2% of the total observations showed excretion). I did not retain most individuals long enough to obtain probable maximum retention times of excreta, but individuals regularly refrained from excreting for up to one month or more, with a maximum of 47 days. Unfortunately I failed to record which individuals excreted, but even if one assumes that the four longest-remaining individuals (47, 39, 39, 35 days) excreted, thereby accounting for the four excretions recorded during this period, seven individuals retained their excreta for over 30 days [34 (2), 33 (4), 32 (1)]. Thus, individuals could routinely retain their excreta for long periods.

In laboratory observations, 29 (67.4%) individuals excreted during the five-minute period after release from the vial, and 14 failed to excrete at this time. This result differed highly significantly from the number expected from the spiders' behavior in the vials, which would predict zero or one excretion ($G = 40.51$, $df = 1$, $P < 0.001$ in a G-test for goodness of fit). None of these individuals excreted in subsequent minutes. When released on the milkweed plants, 28 (73.7%) individuals excreted within five minutes, and 10 did not excrete, a highly significant difference, using the same rationale as the previous test ($G = 55.39$, $df = 1$, $P < 0.001$, same test).

Size of excretions.—Excretions, measured as drops of liquid, differed widely in volume, probably a consequence of how long individuals had retained this material. In the laboratory sessions excretions averaged (± SE) 6.6 ± 1.50 drops, range = 1 to 26 (n = 22 observations); on the milkweeds they averaged 9.0 ± 1.62 drops, range = 1 to 24 (n = 18 observations). Excretions at release in the field significantly exceeded those during laboratory sessions (U = 130.5, $P < 0.03$ in a one-tailed Mann-Whitney U test). On average, retention of excreta at release should exceed those recorded in the laboratory.

The size of excretions at release was positively related to the time that spiders had retained this material ($R^2 = 0.41$, $n = 17$, $P < 0.01$). In contrast, no relationship occurred between the size of excretions of individuals in the laboratory sessions and their retention times ($R^2 = < 0.01$, $n = 15$, $P > 0.9$, same test).

Behavior in the field.—During six censuses run every third day on marjoram, I made 45 observations of the free-ranging spiders out of a possible 120 (number of spiders released × number of counts). I observed a maximum of 11 spiders during a census, although recording 18 of them during one census or another (mean ± SE = 7.5 ± 0.96 individuals). As a result, these spiders might have spent as much as 62.5% (75 of 120 possible observations) of their time away from hunting sites, and a minimum of 27.5%, based on unrecorded individuals later found in the flowers (33 instances). These absences would provide ample opportunity for the spiders to excrete unnoticed. In the process of this census I failed to find a single excretion in the vicinity of a hunting site.

DISCUSSION

Adult female *Misumena* often retain their excreta for long periods under experimental conditions, a trait that should help to facilitate their relatively sedentary behavior. Since these spiders often remain for several days at a time on a superior hunting site (Morse & Fritz 1982), they should experience strong selection to void their excreta carefully. Seldom if ever did the location of such an individual become conspicuous in the field (at least to the human eye) as a result of their disposition of excreta (D.H. Morse, unpub. observ.), including the explicit observations reported here. Spiders possess a large stercoral pocket (cloacal chamber) with a muscular sphincter that allows them to store large amounts of excreta (Seitz 1987).

The clear difference in relationship between size of excretion and time confined accords with the spiders excreting more regularly in the field than under confined laboratory conditions. Under these circumstances the individuals tested upon release in the field would have gone longer without excreting than those measured earlier in the laboratory, and hence, since fed regularly, would have accumulated significantly more excreta. Less likely, they might simply void less prior to the experiments, though I have no basis to support this alternative. Curtis & Carrel (2000) reported that garden spiders fed mealworms excreted over twice a day under otherwise normal field conditions.

The spiders hunting on marjoram would have had little opportunity to excrete without soiling nearby vegetation if they had remained on their hunting sites. They might excrete low in the vegetation without my detecting them. Such behavior would match other observations suggesting that the spiders excrete more readily at sites where the excreta fall far below their hunting areas than where the excreta would fall in their midst (D.H. Morse, unpub. observ.).

Dropping excreta from their immediate vicinity to the vegetation beneath them should make the spiders more conspicuous to other animals on or near the substrate than to those in the canopy or above it. However, dropping their excreta away from their canopy-level hunting sites should make the spiders less vulnerable to most winged attackers, probably the most important threats to spiders in the leafy canopy. When they venture down onto the grassy substrate they expose themselves to attacks from such predators as meadow voles *Microtus pennsylvanicus* and garter snakes *Thamnophis sirtalis* (Morse 1985). In the canopy the egg predator *Trychosis cyperia* (Ichneumonidae) is their most important threat (Morse 1988b). In all of my observations on *Misumena*, I have never seen them preyed upon by birds (Morse 2007); however, the spider wasp *Dipogon sayi* (Pompilidae), rare in the study areas, takes a very occasional small adult female (two observations: D.H. Morse, unpub. data), and large sphecid wasps (Sphecidae), also uncommon in the study areas, are other potential predators, especially of penultimates (Morse 2007).

I have little information on the role of disease or internal parasites, factors that should also favor careful disposition of excreta. I have twice reared horsehair worms (Gordioida) from adult females (D.H. Morse, unpub. data), but these events are relatively rare, since the two records come from a sample of several thousand females collected in the field as adults or penultimates. Tietjen (1980) reported little sign of bacterial or fungal growth about excreta of *Mallos gregalis*. Behavioral traits, however, may play an important role in controlling levels of parasitism of other animals (e. g., Hart 1992; Ezenwa 2004).

Other sparse information on the excretion behavior of spiders suggests that they minimize the apparency of their excreta at their normal hunting level in the vegetation. Curtis and Carrel (2000) noted that the garden spider often leaves its web to excrete, and that it generally does so at night; however, it excretes under its web, consistent with their impression that its major predators are birds and predatory wasps. *Mallos gregalis* concentrated its excreta in parts of an experimental enclosure that it used least frequently (Tietjen 1980). Bonnet (1930) reported that the fishing spider *Dolomedes fimbriatus* (Pisauridae) forcibly cast its excreta out from as far as 3–4 cm from its body. It also frequently excreted before jumping into the water, which could divert a would-be predator, as suggested by Seitz (1987). Although typically presented in the context of predator avoidance, some results may equally well minimize apparency of the spiders to prospective prey, as described by Brown et al. (1995) for pike-minnow interactions. I am unaware of any instances in which excretion patterns of spiders can be unequivocally attributed to minimizing apparency to prey, though this relationship might obtain in many instances, perhaps simultaneously with predator or parasite avoidance. Taken together, these observations, in combination with those of *Misumena* reported here, all suggest that distinctive patterns of excretion behavior may be widespread, but frequently ignored, among spiders.

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